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A. B. CONNER, DIRECTOR

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DIVISION OF CHEMISTRY

Metabolizable Energy of Some Chicken Feeds

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

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SYNOPSIS

This publication is one of a series dealing with the utilization of the energy of animal feeds and of human foods. The metabolizable energy is the energy in the feed eaten less that excreted and is the maximum amount of energy that can be utilized by the animals. No allowances are made for the work of digestion and other losses involved in the utilization of the digested nutrients. Comparison of the heats of combustion found by analysis with the heats of combustion calculated by the usual methods, showed an average percentage difference of 2.1 per cent for 48 samples of feeds, 0.9 per cent for 62 rations, and 2.1 per cent for 136 samples of excrements, with standard deviations of 2.1 per cent, 1.8 per cent and 2.8 per cent, respectively. The values used in the calculations for feeds were 5.7 Calories per gram of protein, 9.47 Calories per gram of fat, and 4.2 Calories per gram of nitrogen-free extract and of crude fiber. The same values were used for excrements with the additional values of 2.735 Calories per gram of uric acid and 5.8 Calories per gram of ammonia. When correction was made for the protein retained, the metabolizable energy calculated from the digestible nutrients agreed well with the value found in 128 tests with growing chickens. The average difference was 2.0 per cent and the standard deviation of the differences was 2.8 per cent. The metabolizable energy (on maintenance basis) of ordinary chicken feeds can be calculated by using the value of 4.4 Calories per gram of digestible protein, 9.47 Calories per gram of digestible ether extract (fat), and 4.2 Calories per gram of digestible nitrogen-free extract and crude fiber. When lactose is present in appreciable quantities, (as in dried whey, dried skim milk, and to a less extent, in dried buttermilk), greater accuracy can be secured by allowing for the fact that its heat of combustion is 3.7 Calories per gram instead of the 4.2 Calories per gram used for nitrogen-free extract in ordinary feeds.

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METABOLIZABLE ENERGY OF SOME CHICKEN FEEDS

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The work here presented is a part of a comprehensive investigation of the utilization of the energy of feeds by animals. Previous publications have discussed the digestibility of some chicken feeds (5), the utilization of energy of feeds by growing chickens (6), the utilization of the energy of wheat products by chickens (7), and the energy values of corn bran, rice bran, and rye flour (8). Other work is in progress. This publication deals with the metabolizable energy of chicken feeds.

The values of feeds have been judged by consideration of the quantities of the various digestible nutrients, of the metabolizable energy, or by measuring the utilization of the food by animals. The metabolizable energy is defined as the total energy less the energy in the solid excrement, in the liquid excrement, and in case of ruminants, the gases produced by fermentation in the process of digestion. The metabolizable energy is, therefore, the maximum quantity of the energy of the food which may possibly be used by the animal. The energy cost of utilization is not included in the metabolizable energy. Mitchell and associates have reported that for chickens metabolizable energy of corn is 331.6 Kg. Calories per 100 gm. or 82.6% (14), 85% (11), and 83% (12) of the gross energy, that of wheat as 80.5% of the gross energy (12), and that of soybean oil meal 52 to 65% of the gross energy (13). Axelson (2) reported the metabolizable energy of some chicken feeds, but the values given were secured by multiplying the digestible nutrients by assumed factors: for protein, 4.7, for fat, 8.3, for nitrogen-free extract, 3.8, and for crude fiber, 3.8. Daikow (3) reported the metabolizable energy of whole barley as being 71.2, 71.8, 71.5, and 72.3%, of whole oats as 62.3%, and of millet as 75.8% of the gross energy. Metabolizable energy used in Texas Bulletin 571 (6) was calculated on the assumption that the metabolizable energy of the effective digestible constituents of the feeds was 4.1 Calories per gram.

A number of digestion experiments have been made at the Texas Agricultural Experiment Station on chicken feeds, with use of chickens from 2 to 10 weeks of age, in connection with studies of the productive energy values of feeds already reported in part (6, 7, 8). The metabolizable energy was determined in connection with a number of these experiments.

Method of Procedure

The chicks were kept in electrically heated brooders in groups of 7 to 10 chickens. The ration being tested was fed for a preliminary period of 3 days followed by a test period of 4 days, during which the excrement was collected. A little less feed was given daily in the collection period than in the preliminary period, so that little feed would remain uneaten. Any scattered feed was collected and weighed. The excrements were collected twice a day and dried in an electric oven at 85°C. The feeds and excrements were analyzed for protein, fat, crude fiber, water, and ash by A.O.A.C. methods. The heat of combustion was determined in an Emerson bomb calorimeter with adiabatic jacket.

Uric acid in the excrement was determined by the following method:

> Weigh 1.4 grams into a 150 cc beaker, add 25 cc of ice-cold alcohol and allow to stand for thirty minutes in ice water. Transfer quantitatively to a 50 cc centrifuge tube and centrifuge until clear. Decant the liquid and wash twice with 25 cc ice cold 95% alcohol. Transfer the residue with 25 cc ether to a hardened filter paper and wash twice with 15 cc ether. Transfer to a beaker and add 25 cc 0.2 hydrochloric acid and allow to stand over night in a refrigerator. Transfer to a centrifuge tube, centrifuge and wash twice with ice cold water. Transfer the residue to a 150 cc beaker with 25 cc water, add 15 cc 0.2 N sodium hydroxide and heat on the water bath until the white particles of uric acid have all dissolved. Centrifuge, pour the supernatant liquid into a 250 cc beaker and wash the residue three times with 50 cc hot water. Evaporate the solution to about 50 cc, transfer to a 150 cc beaker, and continue the evaporation to about 30 cc. Add 5 cc concentrated hydrochloric acid, evaporate to about 25 cc, and allow to stand 24 hours in the refrigerator. Centrifuge and wash twice with ice-cold water. Transfer residue to a Kjeldahl flask and determine nitrogen. The nitrogen multiplied by 3 is uric acid.

Ammonia in the excrement was determined as follows:

> Weigh 1.4 grams excrement into a Kjeldahl flask and add 200 cc water, a drop of lubricating oil, some pieces of sharp glass or broken alundum and about 2.0 grams magnesium hydroxide. Distill into 15 cc 0.2 N hydrochloric acid. Calculate nitrogen as ammonia.

Comparison of Heats of Combustion of Feeds as Found by Analysis and as Calculated

The heat of combustion ~~of~~ ingredients of foods and feeds have been determined by a number of workers. Armsby (Nutrition of Farm Animals) (1) gives the following values in Calories per kilogram:

Animal protein	5700	Animal fats	9500
Vegetable protein	5636	Vegetable fats	9470
Carbohydrates	4185	Ether extract of seeds	9467
Sucrose	3955	Ether extract of roughages	7962

The heats of combustion (Calories per kilogram) of digested nutrients as digested by ruminants are calculated by Armsby as follows:

Protein (wheat gluten)	5975
Protein (assumed average)	5700
Crude fiber	4254
Nitrogen-free extract of hay	4232
Nitrogen-free extract (starch)	4185
Ether extract of hay	8322
Peanut oil	8821
Total organic matter of roughage	4472

The heats of combustion of the feeds here discussed were determined directly with a bomb calorimeter. They were also calculated (1) from the chemical analysis with use of 5.7 Calories per gram for protein, 9.47 Calories for ether extract (fat), 4.2 Calories for nitrogen-free extract, and 4.2 Calories for crude fiber.

In the determination of heat of combustion, the heat evolved was measured by a thermometer calibrated by the U. S. Bureau of Standards, which was graduated at intervals of 0.02°C. and which could be read to an accuracy of about .002 degrees C. The change in temperature during the combustion was usually from 1.6 to 2.0°C. The error of reading could therefore be .004 degrees or about 0.2 per cent. The actual error may be less than this, since the heat of combustion used was the average of 2 or more independent analyses. Other factors could, however, affect the accuracy of the work. A difference of 1 per cent could be ascribed to the error of analysis.

The composition and heats of combustion of 48 samples of feeds as found by direct combustion and as calculated are given in Table 1 together with the ratio between them, expressed as percentage of the calculated value. The average difference between the value found and the value calculated is 2.1 per cent. The standard deviation is 2.8 per cent with the 48 samples, 2.3 per cent if lactose is excluded. On an average, the calculated heat of combustion (4.792 Calories per gram) is practically the same as the heat of combustion found by use of a bomb calorimeter (4.777). The heats of combustion found were higher than those calculated for alfalfa leaf meal (2.9%), casein (4.1%), oat hulls (4.0%), and yeast (1.6%), and lower than those calculated for corn meal (1.9%), low grade flour (1.9%), patent flour (2.3%), lactose (10.7%), rice bran (1.2%), rice polish (1.6%) and starch (2.9%). The differences are small, except for lactose. The calculated value of lactose is too high compared with the value found, which latter, however, (3.717 Calories per gm.) is close to the value of 3.731 given by Emery and Benedict (4) or in the International Critical Tables (10) for lactose containing 1 molecule of water. For feeds high in lactose, such as dried buttermilk, dried skimmed milk, and dried whey, it is probably desirable to use 3.7 calories per gram of nitrogen-free extract in place of 4.2 calories. Other special feeds may also require different values.

Table 1. Percentage composition and heat of combustion of feeds as found and as calculated

Lab. No.		D. E. No.	Protein	Ether extract	Crude fiber	Nitrogen free extract	Water	Ash	Heat of combustion: Found Cal. per gm.	Heat of combustion: Calculated Cal. per gm.	Ratio in per cent
45210	Alfalfa leaf meal	131	20.28	2.75	23.34	35.78	7.80	10.05	3.971	3.911	101.5
48263	Alfalfa leaf meal	180	20.15	2.88	17.04	38.19	7.83	13.91	3.910	3.750	104.3
	Average (2)		20.22	2.82	20.19	36.99	7.82	11.98	3.941	3.831	102.9
47987	Casein		81.30	.13	.23	4.76	9.41	4.17	5.077	4.856	104.6
48261	Casein		81.90	.27	.29	4.67	8.23	4.64	5.030	4.902	102.6
48544	Casein	194–196	84.76	.37	.23	3.67	7.71	3.26	5.273	5.030	104.8
52124	Casein		83.05	.43	.17	3.28	9.01	4.06	5.129	4.920	104.3
	Average (4)		82.75	.30	.23	4.10	8.59	4.03	5.127	4.927	104.1
50740	Corn bran	268	9.40	6.57	12.54	62.06	7.21	2.22	4.346	4.298	101.1
50742	Corn bran	269	10.49	8.16	10.20	61.70	6.92	2.53	4.429	4.396	100.8
50786	Corn bran	270	6.34	3.95	14.79	65.70	7.73	1.49	4.091	4.123	99.2
	Average (3)		8.74	6.23	12.51	63.15	7.29	2.08	4.305	4.272	100.4
48280	Corn meal (white)	167	11.46	2.84	1.48	72.33	10.51	1.38	3.952	4.023	98.2
47955	Corn meal (white)		11.05	3.00	1.39	73.15	9.93	1.48	3.947	4.045	97.6
48260	Corn meal (white)		9.86	4.11	1.36	72.78	10.84	1.05	4.012	4.066	98.7
48440	Corn meal (white)		11.88	4.96	1.58	69.63	10.27	1.68	4.104	4.138	99.2
50868	Corn meal (white)		10.52	2.67	1.01	74.35	10.04	1.41	3.874	4.019	96.4
51556	Corn meal (white)		10.69	3.23	1.12	73.97	9.74	1.25	4.061	4.070	99.8
51960	Corn meal (white)		10.70	2.81	1.06	74.35	9.79	1.29	3.982	4.044	98.5
51824	Corn meal (white)		10.68	2.85	1.04	73.87	10.32	1.24	3.888	4.026	96.6
	Average (8)		10.86	3.31	1.26	73.05	10.18	1.35	3.978	4.054	98.1
48437	Corn meal (yellow)	182	9.89	4.41	2.27	71.06	11.01	1.36	4.148	4.063	102.1
47762	Flour, low grade		13.20	2.24	.43	71.67	11.52	.94	3.854	3.992	96.5
48244	Flour, low grade	169–192	15.07	1.94	.50	70.18	11.46	.85	3.957	4.012	98.6
48436	Flour, low grade	211	18.78	2.08	.50	64.89	12.74	1.01	3.985	4.013	99.3
	Average (3)		15.68	2.09	.48	68.91	11.91	.93	3.932	4.006	98.1
47761	Flour, patent		12.57	.91	.25	73.25	12.55	.47	3.839	3.890	98.7
48243	Flour, patent	168–224	12.83	.84	.24	73.43	12.17	.49	3.753	3.905	96.1
48435	Flour, patent	254–210–225	13.96	1.01	.40	70.88	13.22	.53	3.818	3.886	98.3
	Average (3)		13.12	.92	.30	72.52	12.65	.50	3.803	3.894	97.7
51581	Kafir (blackhull)	281	11.95	3.45	2.33	70.96	9.81	1.50	4.114	4.087	100.7
51582	Kafir (waxy endosperm)	282	11.98	4.06	2.43	70.52	9.16	1.85	4.065	4.132	98.4
	Average (2)		11.97	3.76	2.38	70.74	9.49	1.68	4.090	4.110	99.6

51568	Lactose		.24	.00	.17	98.58	.97	.04	3.717	4.161	89.3
50787	Hydrogenated oil	276		100.00					9.559	9.470	100.9
50788	Hydrogenated oil	277		100.00					9.427	9.470	99.6
	Average (2)			100.00					9.493	9.470	100.3
51609	Oat hulls	296	6.60	1.92	26.10	52.48	7.08	5.82	4.025	3.871	104.0
52971	Corn oil			100.00					9.444	9.470	99.7
52972	Peanut oil			100.00					9.394	9.470	99.2
52970	Soybean oil			100.00					9.497	9.470	100.3
52973	Wesson oil			100.00					9.391	9.470	99.2
	Average oils (4)			100.00					9.432	9.470	99.6
51682	Rice bran	298	13.10	11.17	6.78	50.77	8.98	9.20	4.176	4.225	98.8
51681	Rice polish	297	13.17	15.31	2.10	52.11	9.53	7.78	4.409	4.479	98.4
51683	Rye flour		12.61	1.90	2.16	69.77	11.75	1.81	3.903	3.921	99.5
47956	Starch	196	.49	.09	.26	88.10	10.91	.15	3.660	3.748	97.7
51567	Starch		.64	.07	.16	87.90	11.15	.08	3.666	3.742	98.0
51955	Starch		.63	0	.15	87.83	11.27	.12	3.613	3.731	96.8
52123	Starch		.58	.23	.17	88.46	10.45	.11	3.624	3.777	96.0
	Average (4)		.59	.10	.19	88.07	10.95	.12	3.641	3.750	97.1
47763	Wheat bran	170	17.87	4.18	10.13	52.47	8.93	6.42	4.035	4.050	99.6
48264	Wheat bran		19.24	4.05	9.41	50.64	10.33	6.33	4.078	4.008	101.8
52122	Wheat bran		18.48	4.05	9.93	52.04	8.80	6.70	4.101	4.045	101.4
	Average (3)		18.53	4.09	9.82	51.72	9.35	6.48	4.071	4.034	100.9
47764	Wheat gray shorts		19.03	4.24	6.43	54.81	10.51	4.98	4.002	4.062	98.5
48265	Wheat gray shorts	171	19.50	4.62	6.47	54.94	9.57	4.90	4.119	4.132	99.7
	Average (2)		19.27	4.43	6.45	54.88	10.04	4.94	4.061	4.097	99.1
48262	Yeast		45.42	.99	6.26	33.20	5.53	8.60	4.405	4.343	101.4
51954	Yeast		47.25	1.19	1.08	34.97	7.57	7.94	4.399	4.321	101.8
	Average (2)		46.34	1.09	3.67	34.09	6.55	8.27	4.402	4.332	101.6
	Average (48 samples)								4.777	4.792	99.6
	Average of differences										2.1
	Standard deviations of differences										2.8
	Standard deviations of differences, lactose excluded										2.3

The corn meal was fed in balanced rations A, B or C given in Table 2. The other feeds were fed in similar rations, in which they replaced the corn meal to the extent of 50% with most of the feeds, 15% with oils, and 40% with casein.

The chemical composition and the heats of combustion of the rations as calculated and as found are given in Table 3 with the ratio of the values found divided by the values calculated expressed in per cent. The average difference for the rations is 0.9 per cent, much less than the 2.1 per cent for the unmixed feeds. The standard deviation is 1.8, less than 2.3 per cent found for the unmixed feeds, lactose excluded. These data show that on an average of 62 samples the heat of combustion found is 99.8% of the calculated value.

The heat of combustion can therefore be calculated for the feeds in question from the chemical analyses with an excellent degree of accuracy.

Table 2. Percentage constituents of rations

	47990 corn meal ration (Basal A)	48841 Basal ration (Basal A)	49205 corn meal ration (Basal B)	52133 corn meal ration (Basal C)
Corn meal	6.0	12.0	6.8	....
Alfalfa leaf meal	6.0	12.0	6.0	4.0
Casein	12.0	24.0	12.0	....
Yeast	2.0	4.0	2.0	6.0
Wheat gray shorts	20.0	40.0	20.0	16.3
Calcium carbonate	1.0	2.0	1.0	1.5
Salt	1.0	2.0	1.0	1.0
Tri-calcium phosphate	1.0	2.0	1.0	1.0
Sardilene oil	1.0	2.0	....	....
Cod liver oil	....	....	0.2	0.2
Skimmed milk	....	....	....	10.0
Cottonseed meal	....	....	....	10.0
Corn meal	50.0	....	50.0	50.0

Relation of Heat of Combustion of Excrements as Found by Combustion and as Calculated from the Chemical Composition

The heats of combustion of the dried excrements were measured directly in the bomb calorimeter. They were calculated from the analyses by use of the same values as those used for the feeds, with the addition that the uric acid was considered to have the value of 2.735 Calories per gram (9) and the ammonia that of 5.8 Calories per gram. The numbers of the digestion experiments in which each was used are given in Table 3 and those for the corresponding excrement in Table 4. Analyses of the excrements and comparisons of the heats of combustion as calculated and as found are given in Table 4. The ratio between the calculated heats of combustion and those found by means of the bomb calorimeter are given in Table 4, expressed as per cent. The average of the differences is 2.1 per cent and the standard deviation is 2.8 per cent. These data show that

Table 3. Percentage composition and heat of combustion of rations as found and as calculated

Lab. No.		D. E. No.	Protein	Ether extract	Crude fiber	Nitrogen free extract	Water	Ash	Heat of combustion		Ratio in per cent
									Found Cal. per gm.	Calculated Cal. per gm.	
48266	Basal ration	166	32.79	4.68	5.04	39.42	8.20	9.87	4.203	4.182	100.5
48841	Basal ration	197	34.28	4.99	4.43	36.97	8.71	10.62	4.140	4.168	99.3
51766	Basal ration	291	33.51	2.70	4.71	40.65	8.48	9.95	4.125	4.073	101.3
	Average (3)	....	....	....	....	....	....	....	4.156	4.141	100.4
49206	Casein ration	228,232	49.23	2.11	2.63	30.35	9.70	5.98	4.393	4.393	100.0
49479	Casein ration	240,244	49.35	1.83	2.66	30.81	9.42	5.93	4.345	4.393	98.9
	Average (2)	....	....	....	....	....	....	....	4.369	4.393	99.5
48792	Corn bran ration	199,204	22.10	6.22	9.31	48.49	8.09	5.79	4.301	4.282	100.4
49026	Corn bran ration	215,221	22.00	7.77	8.09	46.16	8.70	7.28	4.291	4.273	100.4
50870	Corn bran ration	236,251	21.01	4.61	8.70	50.64	9.37	5.67	4.107	4.132	99.4
50871	Corn bran ration	237,252	21.30	5.01	7.80	51.03	8.89	5.97	4.156	4.163	99.8
50872	Corn bran ration	238,253	19.25	3.17	9.95	52.92	9.32	5.39	4.099	4.043	101.4
	Average (5)	....	....	....	....	....	....	....	4.191	4.179	100.3
47990	Corn meal ration	162	21.80	3.67	3.59	56.33	9.19	5.42	4.110	4.110	100.0
48274	Corn meal ration	172,176	21.55	4.42	3.20	55.44	9.65	5.74	4.158	4.111	101.1
48466	Corn meal ration	184,188	22.71	5.22	3.26	54.13	8.85	5.83	4.184	4.200	99.6
48791	Corn meal ration	198,203	22.81	5.06	3.18	53.80	9.38	5.77	4.211	4.174	100.9
49023	Corn meal ration	212,218	22.81	4.72	3.13	53.53	10.02	5.79	4.144	4.128	100.4
49205	Corn meal ration	227,231	22.75	3.77	3.00	53.80	10.81	5.87	4.075	4.032	101.1
49478	Corn meal ration	239,243	22.08	2.84	3.03	55.90	10.53	5.62	3.923	4.005	98.0
50869	Corn meal ration	235,250	21.40	2.73	2.86	57.81	9.79	5.41	4.022	4.029	99.8
51359	Corn meal ration	255,263	21.91	3.22	2.65	57.17	9.58	5.47	4.197	4.068	103.2
51570	Corn meal ration	272,278	21.92	3.02	2.77	57.51	9.57	5.21	4.061	4.068	99.8
51684	Corn meal ration	283,287	21.94	3.01	2.90	57.18	9.77	5.20	4.036	4.061	99.4
51833	Corn meal ration	292,299	22.09	2.86	2.82	57.49	9.52	5.22	4.040	4.065	99.4
51956	Corn meal ration	303,308	22.25	2.73	2.73	57.71	9.37	5.21	3.986	4.067	98.0
52133	Corn meal ration	312,320	20.10	3.38	3.43	58.19	8.15	6.75	3.961	4.056	97.7
	Average (14)	....	....	....	....	....	....	....	4.079	4.084	99.9
52332	Corn oil ration	325,329	18.35	16.89	3.48	47.58	6.84	6.86	4.838	4.791	101.0
49025	Clear flour ration	214,220	25.53	2.86	2.70	53.71	9.74	5.46	4.053	4.097	98.9
47992	Low grade flour ration	164	23.49	3.20	3.01	55.78	9.25	5.27	4.088	4.113	99.4
48276	Low grade flour ration	174,178	24.03	3.14	2.74	54.66	10.00	5.43	4.088	4.079	100.2
48468	Low grade flour ration	186,190	25.75	3.48	3.04	52.02	10.29	5.42	4.059	4.112	98.7
	Average (3)	....	....	....	....	....	....	....	4.078	4.101	99.4

Table 3. Percentage composition and heat of combustion of rations as found and calculated—(continued)

Lab. No.		D. E. No.	Protein	Ether extract	Crude fiber	Nitrogen free extract	Water	Ash	Heat of combustion		Ratio in per cent
									Found Cal. per gm.	Calculated Cal. per gm.	
47991	Patent flour ration	163	22.74	2.74	2.93	56.89	9.52	5.15	4.049	4.070	99.5
48275	Patent flour ration	173,177	23.13	2.76	2.67	57.14	9.05	5.25	4.081	4.092	99.7
48467	Patent flour ration	185,189	24.01	2.92	2.76	56.17	8.75	5.39	4.132	4.122	100.2
49024	Patent flour ration	213,219	24.23	2.74	2.59	55.36	9.87	5.21	4.054	4.075	99.5
	Average (4)								4.079	4.090	99.7
51835	Kafir ration	294,301	22.79	2.97	3.43	56.63	8.70	5.48	4.088	4.104	99.6
51836	Kafir ration	295,302	22.58	3.26	3.46	56.87	8.31	5.52	4.085	4.132	98.9
	Average (2)								4.087	4.118	99.3
51572	Lactose ration	274,280	16.87	1.44	2.35	69.71	4.68	4.95	3.895	4.126	94.4
51834	Oat hull ration	293,300	19.88	2.34	15.64	46.88	7.70	7.56	4.173	3.989	104.6
52331	Peanut oil ration	326, 330,332	18.40	17.26	3.53	47.46	6.75	6.60	4.812	4.827	99.7
51686	Rice bran ration	285,289	23.06	7.48	5.56	45.93	8.69	9.28	4.166	4.187	99.5
51685	Rice polish ration	284,288	22.71	9.12	3.37	47.47	8.73	8.60	4.261	4.295	99.2
51687	Rye flour ration	286,290	22.78	2.29	3.48	55.76	10.01	5.68	4.001	4.005	99.9
52333	Soybean oil ration	327, 331,333	18.42	16.85	3.27	47.80	6.97	6.69	4.824	4.793	100.7
49207	Starch ration	229,233	17.63	1.35	2.41	62.86	10.73	5.02	3.862	3.875	99.7
49480	Starch ration	241,245	16.90	1.05	2.32	63.79	10.95	4.99	3.784	3.840	98.5
51571	Starch ration	273,279	16.99	1.43	2.50	64.15	9.92	5.01	3.886	3.903	99.6
51957	Starch ration	304,307	17.62	1.33	2.39	64.73	9.12	4.81	3.870	3.951	98.0
	Average (4)								3,851	3,892	99.0
52134	Starch and casein ration	313,321	19.90	1.87	3.06	60.05	8.73	6.39	3.911	3.963	98.7
51958	Starch and yeast ration	305,310	19.50	1.47	2.40	62.11	9.34	5.18	3.925	3.962	99.1
51959	Starch, yeast and corn oil ration	306,311	19.07	3.61	2.53	61.69	7.99	5.11	4.082	4.128	98.9
51361	Hydrogenated oil ration	257,265	20.56	16.66	3.04	45.99	8.45	5.30	4.740	4.811	98.5
51362	Hydrogenated oil ration	258,266	20.17	16.45	2.69	47.43	7.93	5.33	4.871	4.814	101.2

49208	Wesson oil ration	230,234	20.78	17.66	2.93	43.88	9.29	5.46	4.868	4.824	100.9
49481	Wesson oil ration	242,246	20.50	16.87	2.94	46.39	8.07	5.23	4.863	4.840	100.5
51360	Wesson oil ration	256,264	20.07	17.13	2.76	46.67	8.05	5.32	4.848	4.843	100.1
52136	Wesson oil ration	315,323	18.11	17.14	3.85	47.19	7.11	6.60	4.804	4.801	100.1
52330	Wesson oil ration	324,328	18.51	17.18	3.56	47.29	6.83	6.63	4.830	4.819	100.2
	Average (5)								4.843	4.826	100.4
47993	Wheat bran ration	165	25.60	4.56	7.80	47.31	6.92	7.81	4.216	4.210	100.1
48277	Wheat bran ration	175,179	26.16	4.35	7.45	44.86	9.53	7.65	4.136	4.101	100.8
48794	Wheat bran ration	201,206	26.75	4.51	7.00	44.64	9.09	8.01	4.123	4.125	100.0
52135	Wheat bran ration	314,322	23.87	3.98	8.09	47.03	7.87	9.16	4.055	4.057	100.0
	Average (4)								4.133	4.124	100.2
48469	Wheat gray shorts	187,191	26.37	4.59	5.72	46.87	9.49	6.96	4.147	4.150	99.9
48793	Wheat gray shorts	200,205	26.60	4.89	5.48	47.08	8.84	7.11	4.248	4.189	101.4
	Average (2)								4.198	4.170	100.7
	Average (62)								4.211	4.217	99.8
	Average of differences										0.9
	Standard deviation of differences										1.8

Table 4. Percentage composition of excrements and heat of combustion as calculated and as found

Laboratory Number	D. E. No.	Protein	Ether extract	Crude fiber	Nitrogen free extract	Uric acid	N as Ammonia	Heat of combustion in Cal. per gm.		Ratio per cent
								Found	Calculated	
48133	162	15.75	1.53	11.49	41.48	11.46	.26	3.510	3.601	97.5
48134	163	16.75	1.23	9.61	44.10	11.04	.33	3.605	3.652	98.7
48135	164	16.75	1.48	8.88	44.91	10.65	.32	3.569	3.668	97.3
48136	165	13.20	1.12	13.82	47.52	7.14	.21	3.741	3.648	102.3
48286	166	14.56	1.36	10.37	35.81	13.74	.51	3.241	3.310	97.9
48287	166	14.06	1.27	10.04	34.87	13.59	.46	3.163	3.212	98.5
48305	172	14.00	1.50	10.80	41.70	10.68	.41	3.458	3.466	99.8
48306	173	15.50	1.33	8.92	46.46	10.59	.43	3.617	3.655	99.0
48307	174	16.69	1.43	8.71	44.93	10.92	.41	3.529	3.666	96.3
48308	175	14.13	1.11	12.64	47.47	7.89	.38	3.755	3.679	102.1
48313	176	13.19	1.54	11.11	42.34	10.98	.39	3.439	3.471	99.1
48314	177	17.28	1.39	8.70	41.85	11.43	.45	3.521	3.584	98.2
48315	178	16.50	1.35	8.25	43.59	11.52	.43	3.459	3.591	96.3
48316	179	12.63	1.08	13.19	46.56	8.22	.43	3.709	3.589	103.3
48540	184	15.81	2.20	10.88	43.00	9.54	.30	3.574	3.655	97.8
48541	185	18.38	1.52	9.14	42.60	11.52	.41	3.615	3.708	97.5
48542	186	18.94	1.59	8.58	44.22	10.77	.44	3.583	3.774	94.9
48543	187	15.13	1.47	12.14	47.40	7.89	.32	3.755	3.743	100.3
48592	188	17.38	2.42	10.40	39.47	9.66	.32	3.542	3.603	98.3
48593	189	18.63	1.45	8.83	41.26	10.47	.40	3.515	3.616	97.2
48594	190	17.13	1.67	8.04	43.88	11.10	.47	3.640	3.650	99.7
48595	191	13.00	1.47	11.59	46.48	9.15	.38	3.642	3.597	101.3
48831	198	14.00	1.91	10.34	42.63	10.50	.38	3.611	3.517	102.7
48832	199	10.69	1.48	15.41	53.02	5.37	.30	3.860	3.795	101.7
48833	200	12.94	1.76	11.05	47.71	8.88	.40	3.726	3.645	102.2
48834	201	14.19	2.05	12.03	44.61	9.06	.40	3.674	3.659	100.4
48867	203	12.94	1.99	10.52	42.70	10.89	.39	3.511	3.487	100.7
48868	204	10.19	1.22	15.19	52.52	6.18	.36	3.823	3.739	102.3
48869	205	14.31	1.44	11.35	45.69	9.03	.46	3.678	3.627	101.4
48870	206	14.00	1.22	13.01	44.83	7.83	.51	3.585	3.594	99.8
48969	197	18.69	1.63	10.34	32.04	12.60	.66	3.340	3.387	98.6
48970	197	17.25	1.72	10.33	31.35	14.76	.80	3.313	3.352	98.8
48971	197	15.38	1.65	10.01	34.00	14.85	.74	3.305	3.335	99.1
48972	197	15.44	1.73	11.61	31.33	15.00	.81	3.302	3.310	99.8
48303	167	16.63	2.10	8.02	42.71	14.19	.74	3.564	3.713	96.0
48304	167	17.13	2.02	7.94	45.52	13.02	.72	3.441	3.813	90.2
48334	168	10.56	.95	2.65	68.15	8.25	.47	3.732	3.920	95.2
48335	169	13.69	1.18	3.32	58.90	10.86	.63	3.696	3.841	96.2
48377	170	12.56	1.17	13.79	52.72	4.95	.40	3.846	3.785	101.1
48378	171	13.75	1.25	10.99	51.41	7.20	.49	3.819	3.753	101.8
48420	180	14.69	2.43	18.06	39.46	6.06	.21	3.834	3.670	104.5
48421	181	16.31	1.08	9.31	50.37	6.96	.28	3.727	3.750	99.4
48504	182	17.75	2.57	12.30	47.03	6.87	.41	3.887	3.965	98.0
48505	182	17.88	2.46	11.29	48.58	7.62	.40	3.923	4.003	98.0

48637	183	22.88	2.96	4.91	30.12	12.03	.79	3.447	3.433	100.4
48638	192	21.94	1.08	1.71	28.03	19.80	.47	3.040	3.172	95.8
49084	212	14.69	2.34	9.90	41.93	10.11	.45	3.560	3.544	100.5
49085	213	15.75	1.36	6.79	49.10	9.57	.46	3.569	3.667	97.3
49082	214	18.75	1.61	8.53	39.57	12.06	.55	3.441	3.608	95.4
49083	215	11.69	2.06	13.58	51.00	4.83	.34	3.747	3.732	100.4
49098	218	14.94	2.30	10.30	42.12	10.20	.41	3.566	3.580	99.6
49099	219	16.25	1.42	7.46	47.24	10.41	.45	3.604	3.672	98.2
49100	220	16.38	1.62	7.69	42.65	13.17	.51	3.567	3.595	99.2
49101	221	11.56	1.73	14.67	50.25	6.12	.35	3.589	3.744	95.9
49315	227	14.25	2.11	10.19	41.72	11.07	.40	3.404	3.523	96.6
49316	228	22.13	.96	6.26	24.93	28.05	1.59	3.257	3.524	92.4
49317	229	15.56	1.38	9.90	40.28	10.74	.43	3.446	3.450	99.9
49318	230	14.06	5.16	8.48	43.88	8.88	.39	3.815	3.759	101.5
49320	231	18.94	2.22	9.87	38.29	9.45	.38	3.516	3.597	97.8
49321	232	21.69	1.16	6.56	23.26	28.74	1.74	3.250	3.489	93.2
49322	233	14.81	1.37	10.27	38.67	10.47	.38	3.355	3.342	100.4
49323	234	14.56	4.02	8.82	44.02	8.37	.43	3.550	3.689	96.2
49668	239	15.63	1.79	10.47	40.37	10.11	.47	3.450	3.506	93.4
49669	240	18.13	.88	6.48	22.32	30.84	1.67	3.073	3.268	94.0
49670	241	16.63	1.32	10.79	40.09	7.89	.36	3.483	3.453	100.9
49671	242	13.25	3.61	10.03	41.89	9.54	.40	3.564	3.566	99.9
49818	243	16.63	1.76	10.88	38.26	10.05	.46	3.532	3.486	101.3
49819	244	21.69	.88	7.18	21.55	29.70	1.65	3.217	3.437	93.6
49820	245	15.19	1.26	11.10	39.90	8.19	.32	3.529	3.376	104.5
49821	246	14.50	3.02	9.39	43.89	8.16	.39	3.668	3.601	101.6
51199	235	15.00	1.52	10.17	42.01	9.66	.46	3.546	3.486	101.7
51200	236	11.06	1.25	15.24	51.45	4.77	.33	3.848	3.706	103.8
51201	237	8.94	1.31	14.82	53.72	5.01	.30	3.684	3.674	100.3
51202	238	6.69	.82	16.17	57.27	4.23	.34	3.805	3.687	103.2
51242	250	14.56	1.45	9.46	43.34	11.07	.44	3.521	3.518	100.1
51243	251	9.63	1.36	15.26	53.30	6.06	.38	3.714	3.764	98.7
51244	252	10.44	1.25	14.28	52.59	6.24	.35	3.735	3.720	100.4
51245	253	8.31	.80	15.95	56.71	5.04	.36	3.761	3.769	99.8
51382	255	13.63	1.89	10.10	40.60	10.98	.35	3.416	3.410	100.2
51383	256	13.13	3.78	9.14	40.39	11.16	.40	3.550	3.518	100.9
51384	257	14.06	23.51	8.01	33.67	5.19	.44	5.317	4.949	107.4
51385	258	14.25	3.71	9.81	38.55	11.22	.41	3.572	3.530	101.2
51416	263	15.13	1.54	10.74	38.28	12.21	.33	3.478	3.425	101.6
51417	264	13.81	2.97	9.54	40.58	11.31	.39	3.634	3.509	103.3
51418	265	17.06	22.10	8.19	32.45	4.80	.45	5.224	4.933	105.9
51419	266	13.38	3.35	10.66	39.57	10.95	.38	3.650	3.516	103.8
51611	272	13.13	1.66	10.44	41.45	11.52	.41	3.455	3.429	100.8
51612	273	13.06	1.16	10.30	40.93	11.82	.39	3.389	3.357	101.0
51613	274	8.38	.63	3.73	67.88	5.37	.32	3.546	3.714	95.5
51645	278	13.94	1.78	11.30	39.93	11.07	.40	3.512	3.447	101.9
51646	279	13.13	1.16	10.39	40.18	11.25	.36	3.331	3.317	100.4
51647	280	9.88	.42	3.92	66.52	5.07	.29	3.575	3.720	96.1
51695	283	15.69	1.71	10.02	41.00	10.08	.41	3.547	3.504	101.2
51696	284	15.13	3.49	8.84	38.77	7.44	.17	3.453	3.410	101.3
51697	285	12.13	2.07	12.87	40.33	7.29	.22	3.432	3.340	102.8
51698	286	15.31	1.68	8.21	49.61	7.65	.39	3.779	3.697	102.2
51749	287	13.56	1.57	10.39	41.16	12.00	.44	3.553	3.447	103.1
51750	288	12.00	2.16	9.39	40.96	8.49	.40	3.342	3.263	102.4

Table 4. Percentage composition of excrements and heat of combustion as calculated and as found (Continued)

Laboratory Number	D. E. No.	Protein	Ether extract	Crude fiber	Nitrogen free extract	Uric acid	N as Ammonia	Heat of combustion in Cal. per gm.		Ratio per cent
								Found	Calculated	
51751	289	13.94	1.97	13.79	37.37	6.96	.21	3.430	3.340	102.7
51752	290	16.25	1.73	9.08	46.12	8.79	.36	3.656	3.674	99.5
51852	291	12.63	1.17	10.46	36.78	13.59	.66	3.276	3.231	101.4
51853	291	15.50	1.07	11.20	34.80	12.39	.41	3.238	3.286	98.5
51871	292	13.88	1.73	10.55	41.95	12.12	.35	3.560	3.516	101.3
51872	293	8.44	.86	24.80	45.19	4.83	.19	3.825	3.784	101.1
51873	294	14.94	1.98	11.38	41.71	10.80	.35	3.609	3.591	100.5
51874	295	13.13	2.09	11.63	42.31	11.31	.36	3.696	3.547	104.2
51878	299	12.56	1.65	10.36	41.39	13.11	.39	3.532	3.432	102.9
51879	300	8.31	.82	24.44	45.06	5.16	.23	3.971	3.638	109.2
51880	301	14.75	1.90	11.26	40.24	11.76	.40	3.594	3.635	101.7
51881	302	15.56	1.92	11.17	40.86	10.17	.38	3.620	3.560	101.7
51998	303	15.06	1.47	10.26	39.88	12.09	.34	3.532	3.459	102.1
51999	304	12.13	.91	9.73	44.07	11.19	.33	3.494	3.367	103.8
52000	305	15.69	1.11	10.27	40.15	10.92	.32	3.446	3.439	100.2
52001	306	15.69	1.55	9.57	40.86	10.50	.30	3.453	3.468	99.6
52045	308	15.31	1.41	10.05	38.72	11.64	.34	3.398	3.398	100.0
52046	309	12.00	1.12	9.52	43.05	10.92	.29	3.339	3.321	100.5
52047	310	16.75	1.24	8.98	37.65	11.67	.36	3.405	3.375	100.9
52048	311	17.00	1.49	9.41	38.91	9.72	.32	3.476	3.429	101.4
52163	312	13.38	1.30	10.38	45.55	6.39	.16	3.507	3.424	102.4
52164	313	13.88	.74	9.55	47.09	6.81	.22	3.486	3.444	101.2
52165	314	14.25	1.12	10.72	47.53	6.42	.38	3.621	3.568	101.5
52166	315	13.56	6.48	9.80	41.72	5.94	.16	3.774	3.727	101.3
52175	320	14.19	1.48	10.16	44.28	7.23	.16	3.473	3.448	100.7
52176	321	14.06	.90	9.27	46.58	7.35	.22	3.509	3.450	101.7
52177	322	14.69	1.45	12.22	45.98	5.55	.32	3.645	3.595	101.4
52178	323	13.31	4.41	9.70	43.63	6.36	.23	3.645	3.608	101.0
52555	324	15.81	4.96	9.23	39.62	5.49	.11	3.636	3.583	101.5
52556	325	14.75	7.12	9.79	37.63	5.55	.11	3.712	3.669	101.2
52557	326	14.06	10.79	8.77	36.59	5.85	.13	3.951	3.901	101.0
52558	327	14.94	6.65	9.92	38.14	5.67	.13	3.741	3.669	102.0
52675	328	13.63	3.72	10.40	40.59	6.78	.17	3.569	3.471	102.8
52676	329	14.06	4.50	9.68	40.71	5.70	.18	3.613	3.514	102.8
52677	330	14.44	5.89	9.60	40.10	5.64	.19	3.776	3.638	103.8
52678	331	14.13	3.87	9.80	40.95	5.79	.21	3.535	3.478	101.6
52679	332	13.44	4.88	9.35	42.64	5.76	.18	3.670	3.584	102.4
52680	333	14.00	3.04	8.95	43.38	5.82	.19	3.437	3.458	99.4
Average (136)										100.1
Average of differences										2.1
Standard deviation of differences										2.8

on an average of the 136 samples of excrement, the calculated heat of combustion is the same as the heat of combustion measured in a bomb calorimeter, the ratio being 100.14 to 100.0.

The results show that by means of the factors used the heat of combustion of the excrements can be calculated with an excellent degree of accuracy.

Metabolizable Energy of the Mixtures

The metabolizable energy per gram of the mixtures was ascertained from each of the digestion experiments by subtracting the calories of heat of combustion in the grams of excrement, from the calories in the grams of the feed mixture eaten, and then dividing the difference by the grams of the feed mixture eaten.

The metabolizable energy of the mixtures was also calculated from the digested nutrients, as found in each digestion experiment, with the same factors used in calculating the heat of combustion, namely, 4.2 for nitrogen-free extract and crude fiber and 9.47 for ether extract (fat). However, the value of 4.0 previously used by other workers (15) was used for protein. The metabolizable energy so calculated was found to be too low as compared with the values found by experiment.

This discrepancy is due to retention of protein by the growing chicks. Previous work (6) has shown that growing chicks, similar to these used in this work, retained on an average 56.6 per cent of the digested protein. The value of 4 calories per gram of protein used in the calculation, however, was based on the assumption that all the protein digested was utilized by the animal and excreted in the form of uric acid. This assumption is entirely correct only for animals on maintenance, that is, for those not retaining any of the digested protein. If all the protein eaten (5.7 calories per gram) is excreted as uric acid (2.735 Calories per gram of uric acid (9), equal to 1.3 Calories per gram of protein) the metabolizable energy of the protein would be 4.4 Calories per gram, which is greater than the 4.0 Calories assumed in the preliminary calculation. In the previous work cited the chickens on an average retained 56.6% of the protein digested. The factor (4.4 Calories per gram) for calculating metabolizable energy derived from protein was therefore corrected by adding 56.6% of the value of the uric acid produced from 1 gram of protein, (.73 Calories) which gave 5.13 Calories per gram for protein instead of 5.7 Calories per gram, for the growing chickens.

The apparent metabolizable energy was recalculated with use of the revised factor 5.13 Calories for protein and the calculated results are compared in Table 5 with those found in the 128 metabolizable energy experiments on the rations. The average value found was 2.97 Calories per gram compared with 3.00 calculated, which is 99.1% of the calculated value. The average difference is 2.0 per cent and the standard deviation

Table 5. Metabolizable energy of rations as calculated and as found

Lab. No.		Basal ration	Metab. energy found Cal. per gm.	Metab. energy calculated Cal. per gm.	Ratio per cent
48266	Basal ration	A	2.775	2.764	100.4
48266	Basal ration	A	2.753	2.755	99.9
48841	Basal ration	A	2.648	2.696	98.2
48841	Basal ration	A	2.744	2.802	97.9
48841	Basal ration	A	2.675	2.783	96.1
48841	Basal ration	A	2.814	2.884	97.6
51766	Basal ration	B	2.726	2.715	100.4
51766	Basal ration	B	2.722	2.675	101.8
49206	Casein ration	Sp (B)	3.198	3.191	100.2
49206	Casein ration	Sp (B)	3.153	3.178	99.2
49479	Casein ration	Sp (B)	3.220	3.455	93.2
49479	Casein ration	Sp (B)	3.181	3.253	97.8
48792	Corn bran ration	A	2.130	2.155	98.8
48792	Corn bran ration	A	2.277	2.317	98.3
49026	Corn bran ration	A	2.276	2.267	100.4
49026	Corn bran ration	A	2.153	2.131	101.0
50870	Corn bran ration	B	2.127	2.059	103.3
50870	Corn bran ration	B	2.037	2.152	94.6
50871	Corn bran ration	B	2.294	2.278	100.7
50871	Corn bran ration	B	2.282	2.324	98.2
50872	Corn bran ration	B	1.887	1.773	106.4
50872	Corn bran ration	B	1.818	1.848	98.4
47990	Corn meal ration	A	3.193	3.175	100.6
48274	Corn meal ration	A	3.254	2.964	109.8
48274	Corn meal ration	A	3.191	3.148	101.4
48466	Corn meal ration	A	3.239	3.223	100.5
48466	Corn meal ration	A	3.170	3.171	99.9
48791	Corn meal ration	A	3.213	3.201	100.4
48791	Corn meal ration	A	3.233	3.203	100.9
49023	Corn meal ration	A	3.059	3.057	100.1
49023	Corn meal ration	A	3.192	3.167	100.8
49205	Corn meal ration	A	3.082	3.022	102.0
49205	Corn meal ration	A	3.095	3.038	101.9
49478	Corn meal ration	B	2.962	3.035	97.6
49478	Corn meal ration	B	2.999	3.093	97.0
50869	Corn meal ration	B	3.072	3.062	100.3
50869	Corn meal ration	B	3.053	3.091	98.6
51359	Corn meal ration	B	3.332	3.168	105.2
51359	Corn meal ration	B	3.311	3.213	103.1
51570	Corn meal ration	B	3.123	3.186	98.0
51570	Corn meal ration	B	3.145	3.165	99.4
51684	Corn meal ration	B	3.137	3.103	101.1
51684	Corn meal ration	B	3.100	3.196	97.0
51833	Corn meal ration	B	3.132	3.161	99.1
51833	Corn meal ration	B	3.124	3.197	97.7
51956	Corn meal ration	B	3.033	3.187	95.2
51956	Corn meal ration	B	3.055	3.134	97.5
52133	Corn meal ration	C	2.729	2.860	95.4
52133	Corn meal ration	C	2.916	3.012	96.8
52332	Corn oil ration	C	3.541	3.521	100.6
52332	Corn oil ration	C	3.618	3.601	100.5
49025	Clear flour ration	A	3.076	3.081	99.8
49025	Clear flour ration	A	3.151	3.186	98.9
47992	Low grade flour ration	A	2.999	3.004	99.8
48276	Low grade flour ration	A	3.112	3.068	101.4
48276	Low grade flour ration	A	3.149	3.110	101.2
48468	Low grade flour ration	A	3.035	3.029	100.2
48468	Low grade flour ration	A	2.829	2.896	97.7
47991	Patent flour ration	A	3.070	3.085	99.5
48275	Patent flour ration	A	3.050	3.059	99.7
48275	Patent flour ration	A	3.184	3.188	99.9
48467	Patent flour ration	A	3.210	3.175	101.1
48467	Patent flour ration	A	3.172	3.133	101.2
49024	Patent flour ration	A	2.862	2.860	100.1
49024	Patent flour ration	A	2.984	2.989	99.8
51835	Kafir ration	B	3.067	3.052	100.5
51835	Kafir ration	B	3.044	3.115	97.7
51836	Kafir ration	B	3.022	3.065	98.6
51836	Kafir ration	B	2.987	3.095	96.5
51572	Lactose ration	B	2.021	2.132	94.9

Table 5. Metabolizable energy of rations as calculated and as found—(continued)

Lab. No.		Basal ration	Metab. energy found Cal. per gm.	Metab. energy calculated Cal. per gm.	Ratio per cent
51572	Lactose ration	B	1.989	2.210	90.0
51834	Oat hull ration	B	1.759	1.687	104.3
51834	Oat hull ration	B	1.751	1.796	97.5
52331	Peanut oil ration	C	3.417	3.449	99.1
52331	Peanut oil ration	C	3.566	3.621	98.5
52331	Peanut oil ration	C	3.590	3.628	98.9
51686	Rice bran ration	B	2.810	2.676	105.0
51686	Rice bran ration	B	2.684	2.863	93.7
51685	Rice polish ration	B	3.091	3.178	97.3
51685	Rice polish ration	B	3.118	3.153	98.9
51687	Rye flour ration	B	2.697	2.630	102.5
51687	Rye flour ration	B	2.642	2.710	97.5
52333	Soybean oil ration	C	3.741	3.716	100.7
52333	Soybean oil ration	C	3.748	3.722	100.7
52333	Soybean oil ration	C	3.772	3.723	101.3
49207	Starch ration	B	3.048	3.084	98.8
49207	Starch ration	B	3.124	3.154	99.1
49480	Starch ration	B	2.981	3.059	97.5
49480	Starch ration	B	2.967	3.076	96.5
51571	Starch ration	B	3.098	3.060	101.3
51571	Starch ration	B	3.039	3.147	96.6
51957	Starch ration	B	3.016	3.201	94.2
51957	Starch ration	B	3.045	3.127	97.4
52134	Starch and casein ration	C	2.809	2.872	97.8
52134	Starch and casein ration	C	2.941	3.001	98.0
51958	Starch and yeast ration	B	3.075	3.188	96.5
51958	Starch and yeast ration	B	3.108	3.143	98.9
51959	Starch, yeast and corn oil ration	B	3.172	3.376	94.0
51959	Starch, yeast and corn oil ration	B	3.252	3.248	100.1
51361	Hydrogenated oil ration	B	2.876	2.942	97.8
51361	Hydrogenated oil ration	B	2.809	3.040	92.4
51362	Hydrogenated oil ration	B	3.960	3.948	100.3
51362	Hydrogenated oil ration	B	3.974	3.938	100.9
49208	Wesson oil ration	Sp B	3.680	3.657	100.6
49208	Wesson oil ration	Sp B	3.707	3.702	100.1
49481	Wesson oil ration	B	3.940	3.910	100.8
49481	Wesson oil ration	B	3.863	3.848	100.4
51360	Wesson oil ration	B	3.843	3.866	99.4
51360	Wesson oil ration	B	3.849	3.886	99.0
52136	Wesson oil ration	C	3.611	3.614	99.9
52136	Wesson oil ration	C	3.908	3.892	100.4
52330	Wesson oil ration	C	3.640	3.639	100.0
52330	Wesson oil ration	C	3.675	3.695	99.5
47993	Wheat bran ration	A	2.131	2.197	96.9
48277	Wheat bran ration	A	2.003	2.039	98.2
48277	Wheat bran ration	A	2.163	2.214	97.7
48794	Wheat bran ration	A	2.168	2.223	97.5
48794	Wheat bran ration	A	2.296	2.317	99.1
52135	Wheat bran ration	C	1.615	1.712	94.3
52135	Wheat bran ration	C	1.744	1.811	96.3
48469	Wheat gray shorts ration	A	2.405	2.724	99.2
48469	Wheat gray shorts ration	A	2.431	2.479	98.1
48793	Wheat gray shorts ration	A	2.487	2.489	99.9
48793	Wheat gray shorts ration	A	2.537	2.529	100.3
	Average (128)		2.970	3.000	99.1
	Average of differences				2.0
	Standard deviation of differences				2.8

of the differences is 2.8. These values are very close to those found for the feeds and for the excrements, the differences being 2.1 and 2.1 per cent respectively and the standard deviations being 2.3 and 2.8, but greater than for the rations, which were 0.9 for the differences and 1.8 for the standard deviation. The agreement between the calculated analyses and those found is therefore excellent, when a factor for protein is used which corrects for the protein retained by the growing animal.

The data presented show that the metabolizable energy of the feed of a growing chicken is appreciably less than that of an animal on a maintenance diet. The amount of the difference would depend upon the percentage of the protein retained by the growing animals. In order to calculate the metabolizable energy on a maintenance basis, the value of 4.4 Calories per gram should be used instead of the value of 5.13 Calories found necessary in this work. The data show that such a calculation should be very nearly correct. The actual metabolizable energy is that calculated to a maintenance basis, since the energy retained by a growing animal is part of the metabolizable energy.

Metabolizable Energy of Individual Feeds

The metabolizable energy of the individual chicken feeds fed in the rations was calculated from the experiments here described, with the results given in Table 6. The metabolizable energy can also be calculated from the digestion experiments for a maintenance basis by means of the factors here given, namely, 4.4 Calories per gram of digestible protein, 9.47 Calories for digestible ether extract, and 4.2 Calories per gram of digestible nitrogen-free extract and digestible crude fiber. Since a large number of unpublished digestion experiments with chickens are available and since the metabolizable energy can be calculated from the results of such experiments, the calculation of the metabolizable energy of individual feeds can well await publication of more data on digestibility.

Table 6. Metabolizable energy of feeds fed growing chicks, not corrected to maintenance

Lab. No.		D. E. No.	Total heat of combustion found Cal. per gm.	Metabolizable energy	
				Cal. per gram	In per cent of energy
48706	Corn bran	199	4.421	1.519	34.35
		204		1.812	40.98
50740	Corn bran	236	4.346	1.169	26.89
		251		1.532	35.26
50742	Corn bran	237	4.429	1.819	41.07
		252		1.864	42.09
50786	Corn bran	238	4.091	.775	18.95
		253		1.050	25.67
48800	Corn bran	215	4.421	1.810	40.94
		221		1.565	35.42
	Average (5)		4.342		
48280	Corn meal (white)	167	3.952	3.407	86.20
				3.338	85.58
47955	Corn meal (white)	162	3.947	3.646	92.37
		172		3.769	95.49
		176		3.640	92.22
48260	Corn meal (white)	180	4.012	3.555	88.60
48440	Corn meal (white)	184	4.104	3.737	91.05
		188		3.599	87.69
		198		3.685	91.07
		203		3.560	88.00
50868	Corn meal (white)	235	3.874	3.345	86.33
		250		3.421	88.32
51556	Corn meal (white)	283	4.061	3.403	83.81
		287		3.552	87.47

Table 6. Metabolizable energy of feeds fed growing chicks, not corrected to maintenance —(continued)

Lab. No.		D. E. No.	Total heat of combustion found Cal. per gm.	Metabolizable energy	
				Cal. per gram	In per cent of energy
51824	Corn meal (white)	303	3.982	3.432	88.26
		308	....	3.389	87.17
51824	Corn meal (white)	292	3.888	3.511	90.30
		299		3.544	91.15
48986	Corn meal (white)	212	4.046	3.375	83.42
		218		3.643	90.04
	Average (9)		3.985		
48437	Corn meal (yellow)	182	4.148	3.498	84.32
				3.495	84.26
48898	Flour, clear	214	3.927	3.411	86.86
		220		3.561	90.67
47762	Flour, low grade	164	3.854	3.258	84.52
48244	Flour, low grade	174	3.957	3.484	88.04
		178		3.555	89.84
48436	Flour, low grade	186	3.985	3.328	83.52
		190		2.915	73.15
	Average (3)		3.932		
47761	Flour, patent	163	3.839	3.398	88.51
48243	Flour, patent	173	3.753	3.359	89.51
		177		3.626	96.61
48435	Flour, patent	185	3.818	3.679	96.35
		189		3.603	94.38
48897	Flour, patent	213	3.861	2.983	77.26
		219		3.226	83.55
	Average (4)		3.818		
51568	Lactose	274	3.717	1.192	32.08
		280		1.320	35.50
51609	Oat hulls	293	4.025	.760	18.93
		300		.800	19.79
52973	Wesson oil	256	9.391	8.564	91.20
		264		8.475	90.26
51682	Rice bran	285	4.176	2.391	57.26
		289		2.896	69.35
51681	Rice polish	284	4.409	3.567	80.90
		288		3.461	78.50
51683	Rye flour	286	3.903	2.449	62.75
		290		2.672	68.45
51567	Starch	273	3.666	3.238	88.33
		279		3.476	94.80
51955	Starch	304	3.613	3.428	94.88
		309		3.312	91.66
	Average (2)		3.640		
47763	Wheat bran	165	4.035	1.520	37.68
48264	Wheat bran	175	4.078	1.264	31.33
		179		1.586	39.31
48741	Wheat bran	201	4.063	1.595	39.26
		206		1.851	45.56
	Average (3)		4.059		
47764	Wheat gray shorts	200	4.002	2.232	55.70
		205		2.332	58.58
48265	Wheat gray shorts	187	4.119	2.069	50.23
		191		2.121	51.49
	Average (2)		4.061		

SUMMARY

(1) The heats of combustion of 48 samples of feeds were determined in a bomb calorimeter. The heats of combustion were calculated by use of the factors, 5.7 Calories per gram of protein, 9.47 Calories per gram of fat, and 4.2 Calories per gram of nitrogen-free extract and of crude fiber. The average difference between the values found and the values calculated was 2.1 per cent and the standard deviation of the difference 2.8 per cent, 2.3 per cent if lactose is excluded.

(2) The heat of combustion of lactose found was 3.717 Calories per gram, which is close to 3.731 Calories previously reported by other workers. When the nitrogen-free extract is largely lactose, as is the case with dried whey and dried skim milk, the value 3.7 Calories per gram of nitrogen-free extract would be more accurate than the value 4.2 Calories. However, in an ordinary mixed ration, the lactose content is too low to affect appreciably the value of the nitrogen-free extract.

(3) The heats of combustion of 62 rations, as found and as calculated by means of the same factors as used for the feeds, were in excellent agreement. The average percentage difference was 0.9 and the standard deviation was 1.8 per cent.

(4) The heats of combustion of chicken excrements from digestion experiments were calculated by means of the same values as used for feeds, with the addition of 2.735 Calories per gram for uric acid and 5.8 Calories per gram of ammonia. With 136 samples, the average of the differences is 2.1 per cent and the standard deviation of the differences is 2.8 per cent.

(5) The metabolizable energy per gram of ration was calculated from the digestion experiments by subtracting the number of calories of heat of combustion in the excrement produced from the number of calories in the corresponding quantity of the ration eaten, and then dividing the difference by grams of ration eaten. The metabolizable energy was calculated by use of 4.0 Calories per gram for digested protein, 4.2 Calories per gram of digested nitrogen-free extract and crude fiber, and 9.47 Calories per gram of ether extract. The metabolizable energy calculated was too low. Since previous work showed that growing chickens retain, on an average, 56.6 per cent of the digested protein, correction was made for this retention by use of the value of 5.13 Calories per gram of digestible protein. The average difference between the metabolizable energy for fattening as found by 128 tests was 2.0 per cent and the standard deviation of this difference was 2.8 per cent. This agreement is excellent.

(6) The metabolizable energy for chickens on a maintenance basis of ordinary feeds or rations can be calculated with an excellent degree of accuracy from the digestible constituents by means of the values of

4.4 Calories per gram of protein, 4.2 Calories per gram of nitrogen-free extract and of crude fiber, and 9.47 Calories per gram of ether extract. If appreciable amounts of lactose are present, allowance should be made for the fact that its heat of combustion is 3.7 Calories per gram instead of 4.2 for the nitrogen-free extract in most feeds. There may be other ingredients in special feeds for which allowance must be made to secure increased accuracy of the calculations.

REFERENCES

(1) Armsby, H. P. 1917. The Nutrition of Farm Animals. 228, 229.

(2) Axelson, J. 1937. Der Allgemein Nahwert unserer gewohnlichsten Futtermittel der Huhner. Annalen der Landw. Hochschule, Swedens. Vol. 4.

(3) Daikow, M. J. 1931-2. Untersuchen uber verdaulichkeit, Stoff and Energieweschsel bei huhner als grundlagen fur die rationelle futterung des geflugels. Wiss. Arch. f. Landw. arch. f. Tiernahr u. Tierzucht. 7:571-637.

(4) Emery, A. G. and Benedict, F. G. 1912. The heat of combustion of compounds of physiological importance. Am. J. Physiol. 28:301-7.

(5) Fraps, G. S. 1928. Digestibility and production coefficients of poultry feeds. Tex. Ag. Exp. Sta. Bul. 372.

(6) Fraps, G. S. and Carlyle, E. C. 1939. The utilization of the energy of feeds by growing chickens. Tex. Ag. Exp. Sta. Bul. 571.

(7) Fraps, G. S. and Carlyle, E. C. 1939. Utilization of the energy of wheat products by chickens. Jour. Nut. 18:385-398.

(8) Fraps, G. S. and Carlyle, E. C. 1940. Energy values of corn bran, rice polish, rice bran and rye flour as measured by experiments on baby chicks. Proc. (1939) of the Amer. Soc. for Animal Nutrition.

(9) International Critical Tables. 5:167 (uric acid).

(10) International Critical Tables. 5:166 (lactose).

(11) Mitchell, H. H. 1926. Chickens are efficient energy users of corn. 39th Annual Report, Illinois Experiment Station, 78-79.

(12) Mitchell, H. H. 1927. Wheat found less valuable than corn for chickens. 40th Annual Report, Illinois Experiment Station, 138-139.

(13) Mitchell, H. H. 1930. Soy bean oil meal is poorly utilized feed for chickens. 43rd Annual Report, Illinois Experiment Station, 100-101.

(14) Mitchell, H. H. and Haines, W. T. 1927. The basal metabolism of mature chickens and net energy of corn. Jour. Ag. Res. 34:927-943.

(15) Morey, N. B. 1936. An analysis and comparison of different methods of calculating the energy value of diets. Nutrition Abstracts and Reviews, 6:1-12.